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An Isopach Map and Discussion of the Marine Jurassic of Western United Sates and Canada

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AN ISOPACH MAP AND DISCUSSION OF THE MARINE JURASSIC OF WESTERN UNITED STATES AND CANADA

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A thesis
submitted to the Department of Geology
in partial fulfillment of the requirements
for the Degree of Bachelor of Science
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Montana School of Mines
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INTRODUCTION

Recent demands for petroleum to carry on the war effort have resulted in widespread prospecting in the northern Great Plains. Nearly all oil wells now drilled are of a depth to penetrate the marine Jurassic formations. It is known that these strata differ in thickness from place to place, but information of distribution, thickness, and lithology has not yet been compiled.

It is important to the geologist to know in advance the thickness of the strata to be penetrated, so that the depth of possible oil-bearing horizons may be predicted; this facilitates the placing of the casing, and aids in the interpretation of geologic horizons being drilled.

The upper Jurassic formations of marine origin are favorable oil-bearing horizons as well as potential sources of gypsum and phosphate for the future. It is largely for these reasons that the problem of the thickness of the marine upper Jurassic sediments has been chosen as the subject for undergraduate thesis.

The area under consideration extends from the southern margin of the southwestern provinces of Canada to the northern portions of Arizona and New Mexico. The western margin, along which complete information is scant or lacking, extends from western Utah northward through western Montana into British Columbia. The eastern margin, controlled by the eastern limits of marine inundation, spreads broadly into the Dakotas, and thence progresses in an irregular trace southwestward into New Mexico and Arizona.

The suggestions and help offered by Dr. E.S. Perry and Dr. L.L. Sloss of the Department of Geology of the Montana School of Mines have greatly aided the writer in preparing the isopach map and presenting a brief discussion of related studies, and the writer wishes to express his gratitude and his appreciation.

JURASSIC FORMATIONS

During upper Jurassic time, a body of marine water from the west spread broadly across much of what is now the Rocky Mountains and the western Great Plains. Jurassic sediments were deposited throughout this region. They differ from place to place both in lithological character and in thickness, and individual geologists studying these rocks in their own areas have applied different names to them.

Canada

In the Canadian Rockies, the marine Jurassic beds are generally called the Fernie shale. The formation lies above the lower Triassic Spray River formation and below the lower Cretaceous Kootenay formation. No exposures are available for examination in the plains area underlying the foothills of southern Alberta, but records of deep wells indicate that the formation extends eastward under the plains and gradually thins out against the positive area of the Canadian shield in southwestern Manitoba , where the Fernie has been identified from well cuttings. Jurassic strata are reported by Hume (12-p.260), to be present near Winnipeg. But these sediments are believed to be terrestrial, and marine and non-marine sediments probably interfinger and merge together a short distance east of Regina.

Because comparatively little study of the Fernie formation has been made, detailed information as to definite correlations is not to be had. To the north, the Fernie is tentatively correlated by Warren (25-p.63), with the Pine River formation of Spieker (21-p.118).

Ellis

The name Ellis is applied to the Montana marine Jurassic, and it is thought to represent "only the basal portion of the several thousand feet of marine Jurassic beds in southeastern Idaho, but corresponds closely with the Sundance formation of Wyoming," according to Condit (6-p.114). The name is also used in the most northwestern corner of Wyoming.

Sundance

The Sundance formation is recognized as the marine Jurassic in Wyoming and North and South Dakota. The lower Sundance, which is divided from the upper by an unconformity, is, by Neely (18-p.747), correlated in part with the Twin

Creek formation in southeastern Idaho and western Wyoming. The lower part of the upper Sundance was probably deposited at the same time as the Preuss redbeds, which disconformably overlie the Twin Creek formation. And the Stump, into which the Preuss grades vertically in southeastern Idaho and is partially equivalent to farther east, is thought on paleontologic grounds to be equivalent to the upper part of the upper Sundance.

San Rafael Group

In Utah, northern Arizona, and New Mexico, the general name San Rafael group is given to the upper Jurassic, which is essentially marine. The lowermost formation of this group is the Carmel, and is considered by Baker, Dane, and Reeside (1-p.45), as equivalent to the Twin Creek formation and the lower Sundance.

The Entrada formation, overlying the Carmel, may be considered equivalent to the Preuss. It is not fossiliferous, and thus cannot be directly correlated paleontologically, excepting in so far as it lies between the Carmel and the Curtis, both of which are fossiliferous and can be assigned an age.

The Curtis formation, which overlies the Entrada, may be correlated with the Stump, and in the area of the San Rafael swell in southern Utah it is overlain by the Summerville formation. The Summerville is a separate rock unit in the sections exposed at the swell, but southeastward in Utah

CORRELATION TABLE MODIFIED FROM JOSEPH NEELY

	B.C. and ALBERTA, CAN.	MONTANA	WYOMING and DAKOTAS	IDAHO and WYOMING BORD.	UTAH
	L.CRETACEOUS	U.JURASSIC	U.JURASSIC	CRETACEOUS	CRETACEOUS
MARINE UPPER JURASSIC	?	(U. ELLIS ?)	U.SUNDANCE	STUMP	CURTIS – SUMMERVILLE
		unconformity		PREUSS	ENTRADA
	FERNIE – PINE RIVER	ELLIS	L. SUNDANCE	TWIN CREEK	CARMEL
	MISSISSIPPIAN to TRIASSIC	MISSISSIPPIAN to TRIASSIC	TRIASSIC	L.JURASSIC	L.JURASSIC

it merges into the upper portion of the Curtis formation.

In Colorado, the Entrada, Curtis, and Summerville formations are equivalent to a so-called "Twin Creek limestone," a name used to distinguish it from the Twin Creek formation along the Idaho-Wyoming border. The Carmel formation of the San Rafael group is not persistent into Colorado, and does not have an equivalent in that state.

CONDITIONS OF DEPOSITION

The foregoing sediments were laid down in a sea which invaded the foreland areas from the west in late Jurassic time, encroaching on the northern part of the area first, and overlapping southwestward into eastern Idaho, and thence into the southwestern quarter of Utah. The eastern margin of the sea was limited by a low land area which was subjected to intermittent inundations in the course of the sea's transgression.

The Williston basin, a broad, negative area, carried sea waters that impinged upon Montana and the Dakotas as an arm extending from the Cordilleran geosyncline; this basin persisted through most of the Paleozoic and Mesozoic eras. It projected eastward into Montana from the eastern margin of the geosyncline, and in late Jurassic time was centered along the Montana-North Dakota boundary. The thickness and distribution of the sediments deposited in this eastern extension of the Jurassic seaway is one of the outstanding features shown by the isopach map.

The source of the sediments and the westward limits of the seaway are still much of a problem. Good sections are not available between the Rocky Mountains and the West Coast. Field evidence is obscured by the Lewis overthrust in Montana and Canada, by the Snake River basalts in central Idaho, and by folding, metamorphism and subsequent erosion in the Rocky Mountain province. All of these factors have contributed to making the stratigraphic picture confusing, complex and obscure.

However, it is probable that there was one large seaway extending from the land area of the Great Plains region,westward all the way across what now makes up the Rocky Mountain province, to a high bordering land mass whose eastern edge was the site of the present West Coast. Coarse clastics could not very well have been derived from the eastern foreland, as this was essentially a graded plain with an arid climate in late Jurassic time. They may have come from sources on the Canadian shield and from disconnected, broad island chains in the geosyncline.

The sea encroached upon the foreland gradually and in two phases. In the first phase, the Carmel or Twin Creek Sea, spread almost entirely over Wyoming and Utah, simultaneously flooding the Williston basin, and deposited the Pine River, Fernie, Ellis, lower Sundance, Twin Creek and Carmel formations. The sea then withdrew from part of the foreland into northwestern Utah, western Wyoming, and probably westernmost

Montana, possibly leaving a body of inclosed water in the Williston basin. Red beds and gypsum accumulated in marginal lagoons and embayments in the basin and along the eastern sea margin. In southeastern Utah, clean, white, Entrada sands, partially of eolian origin were deposited; these sands interfinger northwestward into the marine formations of the persistent sea.

The second phase saw the greatest encroachment of marine waters by the Logan or Sundance Sea. In this sea, a questionable amount of Fernie, Pine River, and upper Ellis were laid down, and all of the upper Sundance, Preuss, Stump, Curtis, and Summerville formations.

The climatic conditions were essentially arid, especially in the south, as is shown by the occurrence of red beds and gypsum throughout the thickness of the San Rafael group. Yet, in Wyoming a humid and warm climate is suggested because of an abundance of marine invertebrate life and reptiles. A gradational climatic variation from north to south may be expected, as the difference of latitude is one of the main factors to account for any comparative change.

THICKNESS OF THE SEDIMENTS

Thicknesses of the Fernie where they are accurately measured, may be assumed to be a total thickness of the marine Jurassic, as the Fernie apparently passes conformably into the Kootenay above. This tentatively eliminates any discrepancies of thickness due to erosional unconformities. There is, however, the possibility that the 220-foot section measured at a locality just west of Calgary may be unusually thin as a result of erosion, for Hume (12-p.45B), states that the section of the Fernie "includes 8 feet of yellow-weathering sandstone which may or may not be present on the top on account of an erosional unconformity with the overlying brown sandstones which are considered to be basal Kootenay in age."

Although this indicates that the Fernie is in unconformable contact with the Kootenay in the plains east of the Rocky Mountain foothills, there is no reason to believe at present that this unconformity persists to the west, where sections are thicker and are believed to be more nearly complete.

The thickness of the Fernie is great, as shown in measured sections, some of which are as much as 2800 feet. However, because of the disturbance of the strata by orogenic movements, thus causing difficulty in identification of strata and repetition of measurements across faults, it is not improbable that some of the sections reported are unusually thick. The sections available for study follow a slight northwest trend, 50 to 100 miles east of the British Columbia-Alberta border. Just east of the town of Fernie, the thickness is approximately 800 feet, and it appears to thin out to nearly 200 feet in the northern exposures. East of Banff, its thickness is considerably more, almost 1000 feet, and just northeast of Banff it thickens to 1600 feet, according to Warren

(25-p.62), or to 2600 feet, according to Malloch (14-p.30). This contradiction may be due to the difficulty mentioned above of obtaining accurate measurements; in the same paper, Malloch also gives a section of 2900 feet between the Red Deer and Clearwater rivers, but this may contain some overlying Kootenay. Here as elsewhere in this region, the contact between the Fernie and the overlying Kootenay is seldom very distinct. Still farther north, a section at Nordegg measured approximately 300 feet, and northwest of there is a well-exposed section over 1500 feet thick. Some incomplete sections of the Fernie north of Jasper Park are exposed along the Athabaska river, but northward the formation has not been correlated with other Jurassic sediments by paleontologic or lithologic means. Spieker (21-p.118), describes a 300-foot section of a Jurassic blue-black, petroliferous shale on Pass creek. This he calls the Pine River formation, and it is probably, but by no means absolutely, correlative with the Fernie to the south.

Southward, in central Montana and into the Dakotas, the strata have not been so greatly disturbed, and more accurate information may be gained from a study of sections where they are well exposed.

Prior to the advance of the seas, erosion was prevalent in the Montana area, and Condit (6-pp.120 to 121) remarks

> "Study of the erosion surface from place to place reveals the presence of peculiar yellowish, earthy sandstone, ferruginous, gypseous shale, and local limestone beds, all making up a motley aggregate related neither to the overlying Ellis nor to the underlying formations.

> These heterogeneous materials constitute the sedimentary record of events that preceded or accompanied the advance of the sea from the northwest in late Jurassic time. Their thickness, ranging from a few feet to 100 feet, is direct evidence of slight relief of the land surface, the inequalities of which were leveled to form the floor upon which marine Ellis beds were deposited.

This concept is important, because the lack of topographic highs, either in the shallow Williston basin, or along the foreland areas adjacent to it, affected greatly the thickness and lithology of the sediments being deposited.

Erosion followed deposition of the Ellis and the Sundance, according to Thom (24-p.23), at least locally, and most likely quite extensively, as the erosional unconformity at the top of the Ellis, lower Sundance, and Twin Creek indicates. The writer believes that a substantial thickness of sediments corresponding to the deposits of part of the Twin Creek sea and conceivably even the later Logan sea, has been stripped off of Montana and Wyoming. The disconformity at the top of the Ellis, is manifested by irregular and abrupt changes in thickness demonstrated by isopach lines in western Montana and northwestern Wyoming; this evidence leads one to believe that erosion during the post-Ellis interval may have covered a large area and continued for a long interval of time.

In eastern Montana and the western half of the Dakotas, information was secured from well logs. This is in the Great Plains province, and no Jurassic strata are exposed except along the borders of eroded uplifts. Nevertheless, by interpretations of the well records, the formation is known to be present in southwest Manitoba, and it is thought by Ballard (2-pp.1562 to 1563), that the Sundance underlies part of the western half of North and South Dakota. The eastern limit of the formation is not certain, but most likely it lies 100 to 150 miles east of Bismark, North Dakota.

The thickness of the Ellis and lower Sundance increases noticeably in the Williston Basin, and was likely more than 700 feet thick if erosion was active that far east. Ballard (2-p.1562) states that the Jurassic ". . . probably the Sundance, lies on the beveled edges of strata ranging from Triassic to Devonian in age in the eastern half of North Dakota. The thickness varies from a few inches along the eastern margin of this overlap to 735 feet in the basin north of the Black Hills."

Sections in the western part of Montana demonstrate how variable the thicknesses in that region are. The Ellis in the area east of the Big Snowy mountains has a thickness of 150 feet, while in the Judith basin it ranges from 40 to 65 feet according to Calvert (4-pp.20 to 21). In the Little Belt mountains east of Helena, and in the coal fields south of Great Falls the thicknesses range from 100 to 200 feet. The mountains south of Billings and Livingston exhibit Ellis sections which are thicker, ranging from 250 feet to

400 feet. This thickness becomes less after crossing the Pryor mountains of southern Montana and entering the Bighorn basin of Wyoming.

The thickness of the Sundance in the Bighorn basin is also variable, and Darton (7-p.42), measured a maximum range of 200 to 450 feet on outcrops along the foot of the Bighorn mountains.

In Wyoming, the Sundance and Ellis is thickest in the northwestern part of the state, and it gradually thins until it disappears in the extreme southeast corner of the state. The great thickness of the marine Jurassic along the western border of Wyoming, is due to the presence of the Twin Creek, Preuss and Stump formations.

The Twin Creek of the Idaho-Wyoming border is the thickest of the three formations, in places ranging from 2800 to 3000 feet. It thins very rapidly from southeast Idaho eastward into Wyoming. Likewise, the Preuss and Stump are very thick in the Wyoming-Idaho border area. The Preuss thins rapidly from 1000 feet until it disappears 50 to 100 miles east of the border in Wyoming. The Stump, which is reasonably consistent in thickness, seems to thin slightly from western Wyoming and merge into the upper portions of the upper Sundance in eastern Wyoming and northcentral Colorado.

The San Rafael group is generally a very thick series of sediments, mostly sandstones, representing deposition in the southern reaches of the sea. Recorded thicknesses differ greatly in a particular area, but,in general, the localities of similar thickness can be grouped together, thereby developing a uniformity of variation as shown on the isopach map. Thus, figures for Utah, southwestern Colorado, New Mexico, and Arizona on the isopach map, are from representative thickness sections in a particular locality. The local changes in thickness are most readily explained by Gregory (10-p.69), and he attributes them to three factors: First, there is an unequal development of the San Rafael group, and the formations do not always occur together or in orderly stratigraphic sequence in each locality; second, different amounts of sediments were removed by post-depositional erosion; and third, there is the difficulty in some localities of determining the base of the formations in the field.

Although erosion has affected the thickness of the Jurassic deposits in Utah, Colorado, New Mexico, and Arizona, as well as farther north in western Wyoming and Montana, the San Rafael group is still much thicker than the Ellis and Sundance formations,and doesn't show the irregularity of pattern as the latter formations do on a map of such large isopach interval as the one presented.

DISCUSSION OF THE ISOPACH MAP

A broad, overall inspection of the isopach map reveals three outstanding features. First, there is a thickness of several thousand feet of strata extending along the western borders of Montana, Wyoming, and Utah. These beds thicken very rapidly to the west, and were deposited in a deepening portion of the Cordilleran geosyncline. If information could be had concerning the marine Jurassic even farther west, in central Idaho and eastern Nevada, it might be found that the sediments had been or are thicker here than the thickest sections given for southeastern Idaho; this is merely conjecture, and there has been no direct field evidence yet presented to substantiate this view.

Second, there is an eastern bulge in the pattern of the isopach lines which covers a broad expanse of area. The zero line limits this bulge, and the closed and nearly concentrically arranged isopach lines indicate greater thickness in approaching the middle of the Williston basin, which is centered on the Montana-North Dakota border.

Third, between the Williston basin and the thick belt of Jurassic sediments along the western border of Montana and Wyoming, there is a zone of great irregularity. This zone cuts across central Montana, central Wyoming, and western Colorado. It may be interpreted as the foreland area which locally was subjected to periods of deposition, non-deposition, or erosion during late Jurassic sedimentation. These diastematic pauses or intervals may account for the irregular changes in thickness shown in this zone.

However, it should be noted that more information is available in this central zone than in the Williston basin area. This is obvious from the greater number of isopach points on the map concentrated in western Montana and in central Wyoming than in the area east of there. Therefore, the consideration has to be made that further study and further drilling in the Great Plains, yielding more information of that region, might very well change the isopach pattern of the Williston basin area, possibly to one with the irregularities which are outstanding in the middle zone.

LITHOLOGY OF THE SEDIMENTS

In Alberta, the Fernie formation is characteristically made up of dark-colored shale, very often arenaceous, calcareous, and even bituminous. Warren (25-p.59) says that the sandy shales tend to be platy, and those with the higher clay content are more fissile and darker. To the north, the formation changes to a somewhat sandy facies, replacing the calcareous shales. There are lithologic zones which are distinctive in the Alberta sections. The first is a 5-foot phosphate bed near the base of the formation. It appears to be absent as a lithologic unit to the north, but to the south it is quite persistent.

The second zone, composed of 5 to 30 feet of calcareous sandstone, constitutes an easily recognizable unit from 50 to 150 feet above the base of the Fernie. The thicker sections tend to be sandy, and the thinner sections tend to be more calcareous. This unit is thicker to the north and east, and it may be assumed that the unit thickens and becomes more sandy farther in these directions. The positive mass of land to the northeast, the Canadian shield, was a likely source of these sandy clastics. This unit is also known as the Rock Creek member in Alberta, and is replete with Belemnites.

A number of sandstone beds interlayered with glauconitic shales occur in the Spring Coulee well south of Lethbridge, Alberta. In stratigraphic interpretations, this is some evidence of proximity of a shore line, for glauconite is thought of as a near-shore deposit.

In north-central Montana, south of CutBank, the Ellis consists of black to gray calcareous shales with irregular limestones and fine-grained sandstones intercalated. Eastward, in the Bearpaw mountains south of Havre, the Ellis exhibits a definitely changed section. Reeves (19-pp.93 to 94), describes the bottom third of the formation as a dark-gray, fine-grained, fossiliferous limestone. The remaining two thirds consists of a conformable sequence of black-brown, calcareous, petroliferous shales. These contain large numbers of Gryphaea calceola, and the fossil guards of Belemnites densus.

In the Little Rocky mountains, east of the Bearpaws, and north of the Missouri river, the Ellis is again made up of a basal limestone with overlying shales, according to a section given by Bauer and Robinson (3-pp.174 to 175); the succession of beds and lithology are similar to that of the Bearpaw section.

The Ellis at the Bowdoin dome in northeastern Montana consists of a basal limestone which may be the same that observed in other sections; but it is not so fine-grained, and contains many shaly partings. The overlying shale is changed in lithology, and in general shows interbedded limestone, sandstone, and gypsum. This much constitutes the lower 300 feet of the formation, and above this is another 200 feet of essentially light-colored sandstones which might belong to the Morrison or Kootenai, but which are thought by most geologist to belong to the Ellis.

Information on lithology of the marine Jurassic in the Williston basin can be obtained only from a study of well cuttings. Most of these reflect the shallowness of the sea, and the aridity of the climate of the surrounding areas. The rocks consist of maroon shales, and sandy clay intercalated with limestone beds. The occurrence of glauconite and gypsum is important to stratigraphic interpretation.

The Ellis of central Montana is exposed along the base of uplifts in the vicinity of the Judith and Moccasin mountains. The lowermost portions of the formation there are limestones interlayered with gypsiferous shales, over which are sandstones 150 to 200 feet thick.

North of the Bighorn mountains in the Crow Indian reservation, the lower portion of the Ellis consists of gray sandstones, dark-green shales, and greenish limestones. The upper part of the formation consists of gray sandstones and thin beds of hard, sandy limestones.

The Sundance formation in the Bighorn basin of Wyoming is locally somewhat variable in lithology. The lower beds are made up of grayish-green shales primarily, with masses of soft sandstone in the lower portions. Higher up in the formation the units are hard, sandy limestones. But the Sundance formation as a major lithologic unit throughout the state is of quite uniform lithology, and Neely (18-p.732), describes it as " a basal sandstone which contains fossils in a few localities, a series of red shales and sands which are lenticular and generally unfossiliferous, a series of fossiliferous, dark, marine slabs containing some beds of limestone, and an upper sandy series." The shaly redbeds are not always present, and the sandstones change in character to a slight extent.

Along the Wyoming-Idaho border, and westward into Idaho, occur the Twin Creek, Preuss, and Stump formations. The lower part of the Twin Creek is characteristically a massive limestone, with thin-bedded gray to black shaly limestones or snadstones between the massive members. Locally, lenticular redbeds occur near the base. Fossils are not as abundant here as in the Sundance formation to the east.

The Preuss is a thick formation lying unconformably on the Twin Creek in the Idaho-Wyoming border region, and is composed of unfossiliferous, fine-grained, red sandstones and shales. The Preuss grades into the overlying Stump formation, consisting mostly of thin-bedded, fine-grained, gray sandstones bearing upper Jurassic fossils in a calcareous sandstone bed near the base.

The marine Jurassic of Utah, western Colorado, New Mexico, and northern Arizona, the San Rafael group, is composed essentially of colorful sandstones in thick,slabby, and strikingly massive beds. Most of these beds contain subordinate amounts of gypsum and limestone as compared with the series as a whole. In most of the formations, some cross-bedding can be found, and in the thicker Entrada formation, eolian cross-bedding shows up locally in broad, sweeping curves.

In the San Rafael swell, Gilluly (9-pp.99 to 110), gives a section of the San Rafael group in which the Carmel formation is both limy and arenaceous in the basal part. Upward, it becomes shalier and gypsiferous, and also softer and more easily eroded. The uppermost beds grade conformably into the Entrada formation.

The Entrada at the San Rafael swell is a massive sandstone with interbedded shale. At its base it is a thin-bedded, irregular shale and sandstone. Above these rocks,the material is thick, massive, red-brown, earthy and poorly sorted. The upper surface is eroded and scoured, but the erosion interval was not long, and the Curtis formation was deposited directly upon it. Eolian cross-bedding is common in the lower members, and as these sandy members are traced eastward and southward, they become increasingly more massive until obviously the whole formation is an eolian facies.

The base of the Curtis has variable lithology because of the wide variety of sediments derived from the Carmel erosion surface in the San Rafael swell area. About 40 feet above a basal conglomerate, a series of greenish-gray glauconitic sandstones is present. This member is thick-bedded and forms prominent cliffs and ridges. The upper members are fine-grained shaly sandstones, which grade upward into the overlying Summerville formation.

The Summerville is a thin-bedded, reddish-brown sandstone, with maroon to brown mudstones and shales. The upper part of the formation contains much gypsum as a bedded deposit, and as a whole, the formation gives the appearance on close examination of a rock mass involving a network of secondary gypsum stringers. The formation is disconformably overlain by the Morrison formation in the San Rafael swell area.

The foregoingdescriptions of the San Rafael group, even though general, can be applied to the locality of the San Rafael swell in Utah. An extreme lithologic discontinuity is characteristic of the group, and it cannot be expected that any more than the principal stratigraphic formational units will be distinguishable in widely separated localities.

ECONOMIC GEOLOGY

Petroleum

Gas and oil showings were discovered in the lower gray, cherty limestones of the Spring Coulee well in southern Alberta by Yarwood (26-pp. 1275 to 1276). He also describes a greenish-black shale near the top of this same formation, the Fernie, which contained coal, bentonite, and some petroliferous material.

In Montana, oil has been produced in the Kevin-Sunburst field from Ellis sandstone members known as "stray" sands, and the producing horizon in the Bannatyne oil field 40 miles north of Great Falls is a similar sandstone in the lower part of the Ellis. Elsewhere in Montana, the Ellis is petroliferous in character, but up to the present time, no substantial reservoirs have been developed from the marine Jurassic in new localities.

In Wyoming, 17 per cent of the producing fields pump oil from the Sundance formation. These fields lie in a belt about 100 miles wide, and trend in a southwestern direction across the southeastern part of the state. This belt continues a short distance into Colorado, where Sundance production is of minor importance. Heaton (11-p. 1261), suggests that with respect to the Wyoming-Colorado fields, ". . . conditions under which source beds were formed may have been controlled by successive positions of the shore lines as the sea advanced and retreated." He also indicates other petroleum possibilities in which sands may wedge out updip against marine Jurassic formations in the Uinta, Green River, and Big Horn basins. Neely (18-p.766), mentions a well in the Bighorn basin which gave an initial production of 50 barrels a day from the Sundance. Heaton (11-p. 1262), describes a helium, nitrogen, and methane producing gas well on the Harley dome in east-central Utah. Although not yet of great commercial importance, these several widespread occurrences of oil and gas in the marine Jurassic necessitates its recognition as a potential oil-bearing group of sediments.

Gypsum

Gypsum supports an important mineral industry, with a value in the United States of approximately $50,000,000 per year for calcined and uncalcined products. The gypsum resources in the upper Jurassic formations are large considered as a whole, but not actually extensive enough in most localities to justify mining. However, in Utah, gypsum members of the San Rafael formations are unquestionably large. Beds 30 feet thick are not uncommon, and 6- to 10-foot beds of gypsum occur both in the Carmel and Summerville formations. These deposits are not developed, primarily because gypsum is generally abundant closer to major markets, and the demand is not too great. In central Montana, a 4- to 7-foot bed of gypsum in the basal portion of the Ellis is being mined and processed at Heath, and at one time was mined at Hanover.

Phosphate

In the Alberta coal basins, the basal member of the Fernie formation is predominantly phosphatic. The phosphate beds are essentially oolitic, and have been described by Telfer (23- p. 589) as a black, fine-grained, phosphatic rock which gives off a bituminous odor when struck with the hammer; some high grade, weathered samples gathered near

Crowsnest contained nearly 30 per cent phosphorus pentoxide. Phosphate rock has been taken from the Crow mine bordering British Columbia, but it does not seem likely that the phosphate beds will prove of great economic importance, for they are quite restricted locally, and therefore are not large deposits.

SUMMARY

The marine Jurassic sediments of northwestern United States and Canada cover a wide area extending from northern Arizona into southwestern Canada, and from eastern Idaho and western Montana into the Dakotas. The strata, which were deposited by epicontinental seas from the west in late Jurassic time, differ much in lithology and thickness. In the northern part of the area, the sediments are dominantly shale, whereas in the western and southern part of the area, limestones and sandstones dominate. The map demonstrates three outstanding features of thickness: a western bordering thick zone; a middle irregular zone; and the eastern bulge, or Williston basin zone. The thickness affects costs in drilling, and a knowledge of thickness aids in correlation of underlying strata. From an economic viewpoint, the marine Jurassic formations have already proved valuable as petroleum producing units, and gypsum and phosphate are in the rocks and can be mined in the future if the need arises.

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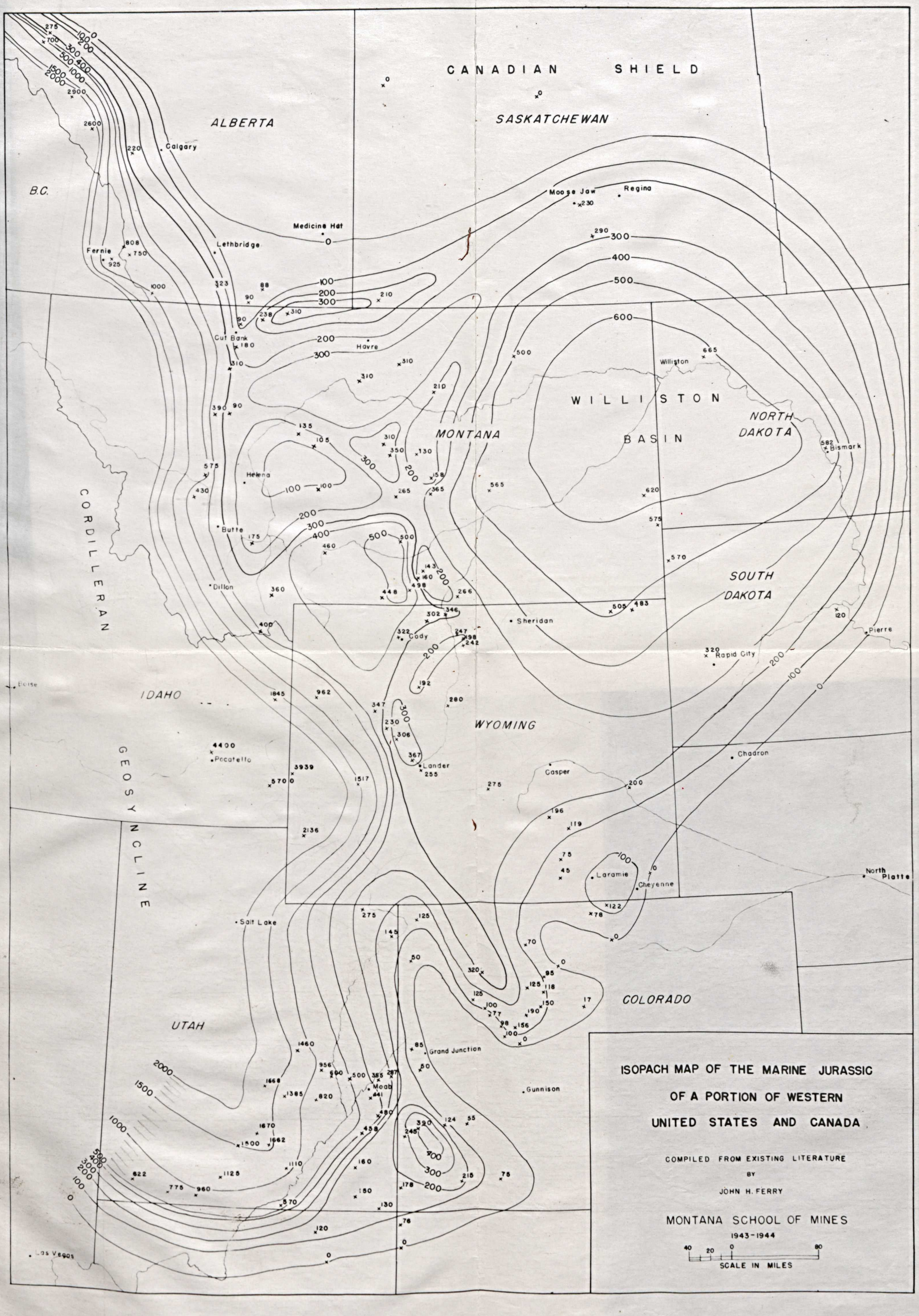

ISOPACH MAP OF THE MARINE JURASSIC OF A PORTION OF WESTERN UNITED STATES AND CANADA

COMPILED FROM EXISTING LITERATURE BY JOHN H. FERRY

MONTANA SCHOOL OF MINES

1943-1944